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Nutritional value of organic acid lime juice (*Citrus latifolia* T.), cv. Tahiti

Valor nutricional de lima ácida (*Citrus latifolia* T.), cv. Tahiti

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Abstract

Acid lime can be used as fresh fruit or as juice to increase the flavor of drinks. Therefore, it is necessary to analyze organic acid lime nutritional composition in order to evaluate if there are important differences among those conventionally produced. No significant differences in total titrable acidity, pH, ascorbic acid, sucrose, calcium, and zinc were found between the acid lime juice from organic biodynamic crops and conventional crops. However, the organic biodynamic fruits presented higher peel percentage than the conventional ones leading to lower juice yield. On the other hand, fructose, glucose, total soluble solids contents, potassium, manganese, iron, and copper were higher in the conventional samples. These results indicated few nutritional differences between organic and conventional acid lime juices in some constituents. Nevertheless, fruit juice from biodynamic crops could be a good choice since it is free from pesticides and other agents that cause problems to human health maintaining the levels similar to those of important nutritional compounds.

Keywords: physical and chemical composition; fruit juice; organic crops; *Citrus latifolia*.

Resumo

A lima ácida pode ser utilizada sob a forma in natura, como suco e para agregar sabor a bebidas. Portanto, é necessário avaliar diferenças na composição nutricional entre limas provenientes de cultivos orgânicos e convencionais. Não foram encontradas diferenças significativas na acidez titulável total, pH, ácido ascórbico, sacarose, cálcio e zinco. Entretanto, os frutos orgânicos biodinâmicos apresentaram maior percentual de cascas e menor rendimento de suco do que os frutos convencionais. Por outro lado, os teores de frutose, glicose, sólidos solúveis totais, potássio, manganês, ferro e cobre foram mais elevados nos frutos orgânicos do que nos convencionais. Estes resultados indicam que existem poucas diferenças nutricionais entre limas ácidas convencionais e orgânicas biodinâmicas. Entretanto, os sucos provenientes de cultivo biodinâmico podem ser uma boa alternativa para escolha tendo em vista serem livres de pesticidas e outros agentes tóxicos, que podem causar danos à saúde humana, mantendo níveis próximos de importantes compostos nutricionais.

Palavras-chave: composição físico-química; suco de fruta; cultivos orgânicos; *Citrus latifolia*.

1 Introduction

Today, a significant increase in organic food consumption has been observed in some countries in the world. Population lifestyle and environmental issues are important factors to explain such increase and must be taken into consideration when production and market strategies are developed (GIL; GRACIA; SÁNCHEZ, 2000). On the other hand, studies have shown that personal factors such as health and food flavor are considered more important by a significant number of organic food consumers than other factors such as environmental preservation, (INTERNATIONAL..., 2005). Biodynamic agriculture, the purest form of organic agriculture, is based on the spiritual understanding of nature, holistic approach, and practice (REIJNTJES; HAVERKORT; WATERS-BAYER, 1994; SOCIEDADE..., 2005). Biodynamic chemical preparations

are certified and monitored with accreditation recognized worldwide (STRINGHETA; MUNIZ, 2003).

Fruit quality and composition depends of pre- and post-harvest factors, and these factors can affect their nutritional, sensorial, and technological characteristics (MORILLAS RUIZ, 2005; CHINNICI et al., 2005; GARCÍA-SANCHEZ et al., 2003).

Acid lime fruits (*Citrus latifolia* Tanaka) are grown almost exclusively in tropical climates. Brazil is one of the most important producers. Acid limes are used as fresh fruit or as juice especially as a blend component added to increase drink flavor (FOOD..., 2003).

The objective of the present study was to evaluate the contents of ascorbic acid, minerals, sugars, total soluble

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solids, pH, titrable acidity, and juice yield of the acid lime juice, cv. *Tahiti*, from conventional and organic biodynamic production systems.

2 Material and methods

2.1 Raw material

Nineteen kilograms of acid lime (*Citrus latifolia* Tanaka.), cv. *Tahiti*, from a conventional production system, cultivated in São Paulo and purchased at the Central de Abastecimento do Estado da Guanabara (CADEG), a farmers' market in Rio de Janeiro, and 18 kg of organic biodynamic acid lime (*Citrus latifolia* Tanaka.), cv. *Tahiti*, supplied by Bom Jesus Farm, São Paulo, Brazil were used. The acid lime fruits were harvested in May/June 2005.

2.2 Experimental design and statistical analyses

The fruits were coded as: CL (conventional acid lime) and BL (biodynamic acid lime). Each group was sorted into 5 lots with 10 samples per lot. All analyses were carried out in triplicate. The CL lot had around 3.8 kg and the BL lot around 3.6 kg of acid lime. All data were treated by analysis of variance (ANOVA). The comparison among the treatment averages was made using the Least Significance Difference test (LSD) at the level of 5% of probability. All statistical analyses were carried out using Statistica software version 5.1.

2.3 Acid lime juice processing

The raw material was selected, weighed, and washed to remove the soil residues, and the sample sanitized by immersion in chlorinated water, 100 mg.L⁻¹, for 10 minutes. The acid lime juice was extracted using a multiprocessor (Wallita) coupled with a finisher to remove the pulp. The fruit juice was conditioned in identified PVC containers and stored under freezing at -10 °C for 2 weeks.

2.4 Acid lime juice yield

The yield of both experimental groups (CL and BL) was calculated by the ratio of total fruit weight and final juice weight.

2.5 Total titrable acidity and pH

The pH and total titrable acidity were determined using a potentiometric titration equipment (Metrohn 798MPT Titrino) in accordance with ISO 750:1998 (E) method (INTERNATIONAL..., 1998).

2.6 Total soluble solids (°Brix)

Total soluble solids (°Brix) were measured using an Atago TR 101 refractometer at 20 °C (ISO 2173:1978 - E) (INTERNATIONAL..., 1978).

2.7 Vitamin C (ascorbic acid)

Vitamin C content was determined by high-performance liquid chromatography (HPLC) using an Alliance chromatograph

coupled with BioRad HPX87H column, UV/visible detector, sulfuric acid 0.1N as mobile phase, and a 0.7 mL/minutes flow. The sample preparation performed with 2.5 g of acid lime juice, diluted with sulfuric acid 0.1N, and ultrasonicated for 10 minutes. The volume was completed to 25 mL with sulfuric acid 0.1N in a volumetric flask, filtered in a Wathman n°. 1 filter, stored in glass flasks, and kept at -18 °C. Vitamin C quantification was performed by injecting 20 µg.mL⁻¹ of ascorbic acid standard solution (number A92902, Sigma-Aldrich) (ASSOCIATION..., 2005).

2.8 Soluble sugars (fructose, glucose and sucrose)

Soluble sugars were quantified by high-performance liquid chromatography (HPLC). The Alliance HPLC system was used coupled with a Waters 044355 reversed-phase column and a refractive index detector. The mobile phase consisted of Milli Q water/acetonitrile 25:75 at a flow rate of 1 mL/minute. Standards for quantification included fructose, glucose, and sucrose (0.05 g.mL⁻¹ each), which were from Sigma-Aldrich (n°. 47748, 47289, and 47249, respectively). Around 1.0 g of acid lime juice samples were added to 5 mL of Milli Q water and treated with ultrasound for 20 minutes, followed by the addition of 5 mL of acetonitrile, and the final volume was completed with Milli Q water up to 25 mL. All samples were filtered using Wathman n°. 1 filter, stored in glass flasks and maintained at -18 °C (ASSOCIATION..., 2005).

2.9 Minerals

The minerals were measured using the µ-Synchrotron Radiation Excited X ray Fluorescence microprobe (TXRF) from the National Laboratory of Light Synchrotron, Campinas - São Paulo. Each sample was prepared from an aliquot of 500 µL of acid lime juice. The samples were digested with acid nitric (HNO₃) 65% (Merck) and hydrogen peroxide H₂O₂ 30% (Merck) under 60 °C heating for 6 hours. 50 µL of gallium solution (102 µg.g⁻¹) was then added as internal standard to an aliquot of 500 µL of acid lime juice. An aliquot of 8 µL was transferred to the Lucite reflecting support placed under infrared light to be dehydrated. This support was placed horizontally to the high pure germanium detector (HPGe) - with resolution of 140 eV in 5.9 keV, and the aliquot was excited with a white beam of irradiation with maximum energy of 20 keV. The excited aliquot was filtered through of 0.5 mm of aluminum at an incidence angle of 1.0 mrad. The sample and standard measuring time was 100 seconds, and the characteristic X ray specters obtained were analyzed with the software X rays Quantitative Analysis System (AXIL) [192], distributed by the Atomic International Energy Agency (AIEA). The X ray intensities were collected for each element and associated with error data probability. The analyses were carried out using three replicates, and the HNO₃ 65% and H₂O₂ 30% solution was used as blank sample (ASSOCIATION..., 2005).

3 Results and discussion

3.1 Acid lime juice yield

The acid lime juice yields of the conventional method (CL) and biodynamic method (BL) were 56.0% (± 1.22) and 44.2%

(± 3.43), respectively. Table 1 shows that the CL juice yield was significantly higher than the BL juice yield.

This significant difference was probably due to the higher percentage of fruit peel in the biodynamic fruits ($49.2\% \pm 2.70$) than in the conventional ones ($40.6\% \pm 2.31$), which may decrease total juice volume (Table 1). The fertilizer level used can influence citrus quality. According to Chitarra and Chitarra (1990), some minerals such as potassium, magnesium, and zinc applied in the soil to increase fruit size and weight.

Fruit juice yield can be reduced by applying high concentrations of nitrogen and potassium in the soil, thus increasing peel thickness. The relative humidity and temperature of the environment can also influence peel thickness in *citrus* (CHITARRA; CHITARRA, 1990).

3.2 Total soluble solids, total acidity, and pH

The results of total titrable acidity were 6.05 ± 0.157 for CL samples and 5.98 ± 0.502 for BL samples. Soluble solids were 8.42 ± 0.89 and 7.63 ± 0.379 for CL and BL samples, respectively. These results agree with those observed by Marin et al. (2002) obtained for the varieties Fino and Verna. The fruit juice pH was 2.81 ± 0.011 and 2.78 ± 0.044 for CL and BL samples, respectively. The statistical analyses indicated no significant differences between CL and BL fruit juices for total titrable acidity and pH; however, the soluble solids content of the BL group was lower than that of the CL group (Table 1).

Fruit composition and aroma can be modified by sunlight intensity and pesticide use (MATTHEIS; FELLMAN, 1999). The intense sun's rays the fruit receives can influence total soluble solids but not total titrable acidity. Phosphorus fertilization leads to a reduction of total acidity and soluble solids (CHITARRA; CHITARRA, 1990).

The organic acid and sugars in fruit juice are very important. Fruit juice ratio is the relation between °Brix and acidity. Significant differences in juice fruit ratio can affect its chemical and sensorial characteristics. Therefore, this information is crucial for technological process optimization and fruit juice acceptance by consumers (MATTHEIS; FELLMAN, 1999; CHINNICI et al., 2005; MARSH et al., 2006).

Total titrable acidity of both groups was found to comply with the Brazilian Identity and Quality Standard legislation that determines a minimum of $5 \text{ g} \cdot 100 \text{ g}^{-1}$ in citric acid for acid lime juices. In addition, total titrable acidity content, solid soluble, and pH values were very similar to those found in a previous study carried out by Pedraño et al. (1999).

3.3 Vitamin C (ascorbic acid)

The ascorbic acid contents were 22.86 ± 0.426 and 22.80 ± 2.084 for CL and BL fruit juices, respectively. No significant difference was observed between CL and BL fruit juice samples (Table 1). These results are also in accordance with the Brazilian Identity and Quality Standard (BRASIL, 2000) that determines a minimum of $20.0 \text{ mg} \cdot 100 \text{ g}^{-1}$ for ascorbic acid in acid lime juice.

Table 1. Conventional and biodynamic acid lime juice composition.

	CL	BL
pH	2.81 ^a (± 0.011)	2.78 ^a (± 0.044)
Acidity (g.100 g ⁻¹ citric acid)	6.05 ^a (± 0.157)	5.98 ^a (± 0.502)
Soluble solids (°Brix)	8.42 ^a (± 0.189)	7.63 ^b (± 0.379)
Vitamin C (mg.100 mL ⁻¹)	22.86 ^a (± 0.426)	22.80 ^a (± 2.084)
Fructose (g.100 g ⁻¹)	0.98 ^a (± 0.100)	0.66 ^b (± 0.058)
Glucose (g.100 g ⁻¹)	0.89 ^a (± 0.051)	0.54 ^b (± 0.053)
Sucrose (g.100 g ⁻¹)	0.07 ^a (± 0.058)	0.12 ^a (± 0.021)
K (µg.g ⁻¹)	376.79 ^a (± 33.270)	240.70 ^b (± 17.112)
Ca (µg.g ⁻¹)	23.24 ^a (± 0.693)	23.41 ^a (± 0.856)
Mn (µg.g ⁻¹)	0.08 ^a (± 0.004)	0.04 ^b (± 0.000)
Fe (µg.g ⁻¹)	1.71 ^a (± 0.078)	0.75 ^b (± 0.134)
Cu (µg.g ⁻¹)	0.35 ^a (± 0.014)	0.20 ^b (± 0.007)
Zn (µg.g ⁻¹)	0.29 ^a (± 0.064)	0.43 ^a (± 0.014)

Same letters in the same column present no statistical differences for LSD test ($p < 0.05$).

LC - conventional acid lime juice; LB - biodynamic acid lime juice.

The L-ascorbic acid (AA) is the main active form of vitamin C, and it is reversibly oxidized to dehydroascorbic acid, also presenting biological activity (ARANHA et al., 2000). It is widely spread in vegetal cells and has a crucial function in their growth and metabolism (HERNÁNDEZ; LOBO; GONZÁLEZ, 2006). The fruit juices, especially *citrus* juices, are important AA sources (KABASAKALIS; SIOPIDOU; MOSHATOU, 2000), and are synthesized from sugars supplied through photosynthesis (LEE; KADER, 2000). Temperature control is the main post-harvest factor to maintain this vitamin concentration, with losses increasing significantly with temperature increase and storage time (LEE et al., 2006). The vitamin C content in fruit and vegetables can be influenced by some factors such as: genotypic differences, pre-harvest conditions, maturity stage, harvest methods, and post-harvest handling system. In *citrus*, vitamin C concentration decreases with ripening. However, vitamin C content is higher in mature fruit than in green fruit because fruit juice volume and fruit size increase in mature fruit. The vitamin C content of *citrus* juice increases with potassium soil fertilization and decreases with high nitrogen fertilization (LEE et al., 2006).

Morillas Ruiz (2005) observed that ecological crops of tangerines and lemons presented higher antioxidant activity and vitamin C content than conventional fruit crops. However, the opposite was observed in oranges, in which the conventional crops had higher vitamin C content than the ecological ones. Additionally, Borguini and Silva (2007) did not find significant differences for the ascorbic acid content in Carmen cultivar tomato samples, cultivated in both organic and conventional crops. On the other hand, for Debora cultivar, the same authors observed a higher ascorbic acid content in conventional tomato crops than in organic tomato crops. Therefore, it is clear that a standard behavior was not identified.

3.4 Soluble sugars (fructose, glucose, and sucrose)

The fructose and glucose contents of LB samples were significantly lower than those found in the LC samples ($p < 0.05$) (Table 1). This can explain the lower soluble solids content in the BL

juice samples. Many different factors could have contributed to the low soluble sugar content in the LB samples. One of them is mineral fertilization, whereas potassium is the crucial mineral element causing starch accumulation in *Citrus* leaves (LAVON et al., 1995).

On the other hand, for *citrus* fruits, delay in the development of dry matter accumulation in the developing fruit increased markedly exceeding the photosynthetic capacity of leaf inflorescence (MARTINEZ-CORTINA; SANZ, 1991). The carbohydrate reserves previously accumulated in the leaves can be mobilized and sucrose levels can decrease showing a limitation in carbohydrate supply.

The shortage of free sugars may trigger ethylene synthesis since defoliation, which drastically reduces sucrose transport to the fruit, increases ethylene synthesis (ORTOLÁ; MONERRI; GUARDIOLA, 2007) and 1-aminocyclopropane-1-carboxylic acid (ACC) accumulation (GÓMEZ-CADENS et al., 2000).

3.5 Minerals

Significant differences were observed between the LC and LB groups for calcium (Ca) and zinc (Zn) contents. The conventional lime juice presented higher potassium (K), manganese (Mn), iron (Fe), and copper (Cu) (Table 1).

It can be observed that the Ca, K, Mn, and Zn contents for both samples were rather lower than those reported by the USDA (UNITED..., 2005). For whole lime juice, these contents were expressed in $\mu\text{g}\cdot\text{g}^{-1}$ as: 140; 1170; 0.18; and 0.8, respectively. On the other hand, the values for Fe ($0.9 \mu\text{g}\cdot\text{g}^{-1}$) and Cu ($0.27 \mu\text{g}\cdot\text{g}^{-1}$) were slightly lower for the LB group than for LC.

These differences can be caused by pesticides/fungicides used in conventional methods, which increase the minerals contents in the soil. The biological activity and pH of the soil can influence the bioavailability of the minerals (HE; YANG; PETER, 2005). The distribution of minerals in the fruit is also an important factor. Gorinstein et al. (2001) reported significant differences between mineral contents of lemon juice and its peels.

4 Conclusions

No significant differences in total titrable acidity, pH, ascorbic acid, sucrose, calcium, and zinc were found between lime juice samples from biodynamic and conventional crops production systems. On the other hand, the organic biodynamic fruit presented lower fructose, glucose, total soluble solids contents, potassium, manganese, iron, and copper as well as higher peel percentage than the conventional lime group producing lower juice yield in the biodynamic crop samples.

Nevertheless, fruit juice from biodynamic crops could be a good choice since it is free from pesticides and other agents that cause problems to human health maintaining the levels similar to those of important nutritional compounds.

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